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# A Review on Structural Analysis of Leaf chain in Counterweight Balancing of Machine Tool Using Finite Element Method

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**Abstract -***Whenever the sudden motion take place in a counterweight balancing of machine tool due to inertia effect of the heavy mass of machine tool head with counterweight exert large amount of forces in the chain link and in order to prevent failure of the chain vertical motion of the machine tool head take place at lower velocity, by increasing the efficiency of a leaf chain, we could further increases in the vertical motion of machine tool head and is still a challenges for the designer to provide not only the better stress resistance or wear resistance of a chain but also the weight saving in a chain material during its design, this could increases the chain performance as well as it could be cost efficient. The design parameters on which the efficiency of the leaf chain depend should be considered by the designer, by analyzing fatigue life and strength of a leaf chain. The CAD model of the leaf chain is developed using a Creo parametric software and finite element analysis is conducted by the help of ANSYS software, under which analysis is done by plotting sensitivities graph for the various design parameters and the factor effecting strength and fatigue life of a leaf chain, considering effect on chain link plate under a Response surface Methodology.*

***Key Words***: **FEA Analysis, Fatigue life, Leaf chain, Response Surface Optimization, Pin diameter, Counterweight balancing, Load to inertia ratio.**

## 1. INTRODUCTION

Machine tool of the larger size in order to perform the desired operation. This consist of the machine tool with the high power and high cutting speed due to that its self-weight of the tool increases a lot, and whenever these larger work pieces are under various machining, it is not possible to move the work piece according to the required operation performed and due to that we have to move machine tool head its self to reach the desired position in which the operation are to be performed on the plane of the work piece. In the whole process machining operation, machine head which consist of the tool in its head, it have to move from one position to another position with a certain speed according to the requirement for that particular operation, which consist of the 3D motion of the machine head in a horizontal plane and also in vertical plane. For this type of the machine tool which consist of the moving head with tools in it and have easily performed horizontal motion or in case of some machining tool its bench consist of the moving platform for the motion of the work piece in a positive as well as negative axis in a horizontal plane. Whereas in case of vertical motion of the heavy machine tool heads it required some weight to counter the self-weight of the machine and to support counter weight for the following machine tools it is connect with a link called leaf chain. This chains are designed to carry a very large amount of tensile loads, as these have high tensile strength and used in a combination with different type of lacing of chain.

### 1.1 Lacing of leaf chain

Odd plate combinations: In this type of combinations the inner link of leaf chain containing the odd numbers of link plate while the outer links contains the even number of link plates, on the other hand a leaf chain with odd plate combination shows a optimum strength in fatigue and a link with larger face provide optimum resistance to wear.

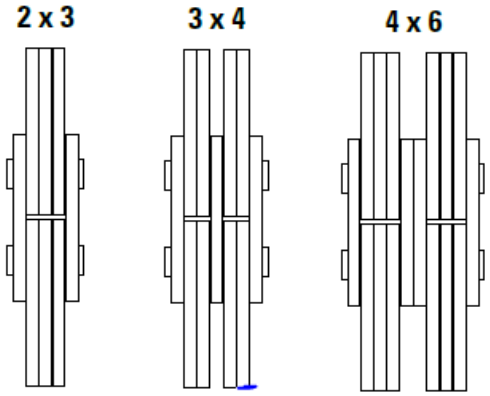


**Fig -1**: Odd plate combination of leaf chain

Even plate combinations: In this type of combinations the inner link of leaf chain as well as the outer link of the leaf chain contains the same number of link plates, as this type of leaf chain comes under the "AL" type chain configuration and under its working conditions experiences a lighter weight as compared to "BL" type leaf chain.

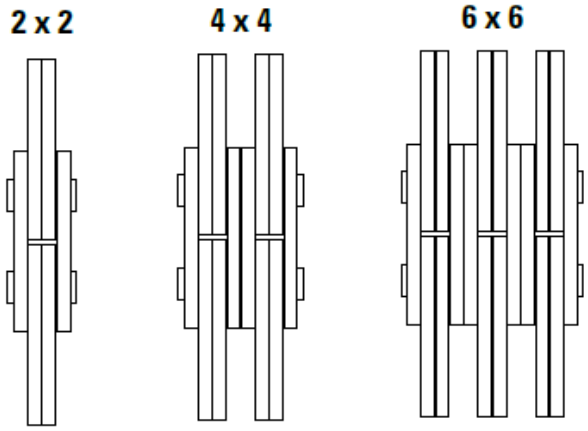


**Fig -2**: Even plate combination of leaf chain

### 1.2 Response surface optimization method

Response surface Methodology (RSM) is a collection of statistical techniques as well as mathematical techniques used to perform the indispensable functions which include configurations of series of experiments or design for appropriate prognostication of a responses from y. Experimental model are installing to obtained data for the selected design. Optimum conditions are determined on the model inputs (which are controllable) variables that result to a minimum and maximum response within the area of interest, basically this is a method to achieve optimization or the analyzing the input variables which are let's consider X1, X2, X3……Xn. On which the output parameters or results are dependent for e.g. Y1, Y2, Y3……Yn. So basically the input variable contains upper limit and lower limit of that parameters for which the chart are prepared for the input parameters and the output parameters and according to the defined value the outputs results are generated, and after that various graphs and charts are generated through which user can easy identified, what are the inputs parameters through which a optimization achieved.

### 1.3 Design of experiment (DOE)

DOE is a robust data analysis and collection tools. It is a standardized method for determination of the interrelation between the output of the process and the input factors which affecting the process. It allows manipulations of various input factors, examine their noticeable effect on a user select responses (output), by manipulating the various inputs at the identical time, DOE can recognize critical interactions that may over look when investigating with single factor at a one time. Possible amalgamations can be examined or only some portion of possible combinations.

## 2 Literature review

Kim Gyung-Ho [1] machine tools are designed to performed motion in all of the 3-Dimensdional axis of the work space, and motion in these axis are required to performed their machining operations for which machine tools are designed, but the machine tools which have a very large amount of its own weight, which are designed to use in a heavy machining operations, these machine tools could easily performed horizontal motions with a little effort or no such issues arises when the horizontal motion take place, or for the horizontal motion some machine beds are available in a configuration in which work-piece can be moved horizontally in a positive as well as negative x-axis, but in the case of vertical motion (which is along the y-axis) of the heavy weight machine tools head its often seen that these machine tool have worse performance, and this performance differences arises due to the structure differences for the motion along x and y axis in a working space of machine tool, the major contribution for the worse performance during vertical motion it the large self-weight of the machine tool attached with counterweight in order to balance it and due to counterweight motion with the help of leaf chain could develop a vibration in a machine tool structure and it also limited the moving velocity of machine tool head along vertical axis to prevent chain link failure.

C.W. Huang [2] as we know machine tool with counterweight balancing system during motion in vertical direction generates lots of vibration in a machine tool structure this affect the machining operations as well as motion of the tool in a work space, during motion of the counterweight in a heavy machine tool system inertia effect in a whole causes elastic jump in a leaf chain structure and releases of the potential energy in the whole structure of the connected chain, this could lead to the failure of the connected link chain, investigation of these effect can be analyzed with the help of the software called Nastran, as we know in a machining process tool have to move in pre-planned path in order to perform their functions on the work piece, during that motion sudden stop and sudden start of the machine tool head generated extra amount of forces on the whole structure connected with the chain link arrangement.

Zheng Zhang [3] while designing machine tool for the various machining operations for the machine tool head move with a high acceleration as well as the high velocity the feed of that machine plays important role and this consist of the subsystems which make more complicated for analysis purpose, so for the analysis purpose new method is adopted in which the detailed analysis of the resembling characteristic between inertia ratio and required motion process, by this method output results show that when feed system of the machine tool are operated for the low velocity and low acceleration the inertia ratio have very little effect on the system, whereas when feed system are operated at higher velocity it play important role while designing for the machine tool moving mechanism.

K.H. Wehking [4] chains with different embodiments or simply a optimum design arrangement are used in many areas of technology and have a corresponding longer history of improvement which make it further development

according to its needs. Earlier applications of the chain link as a mechanical element for transmitting power was already used in 1stcentury B.C, it was also used by Roman architect and in Marcus Vitruvius engineering in the form of forged chain link on a bucket elevator which was used for the lifting of water from the well or for lifting materials, as a development of chain take place and one of the important factor where manufacturer should pay attention while designing the chain link is the fatigue life of a chain.

C. Cenac [5] as the demand of the working mechanical components are increasing nowadays, so it require not only wear performance against the working conditions but also require a better fatigue performing chain links. Last few decades includes series of development in the performance of the chain links and the selected material properties would spread of modern analysis techniques, which made possible because of availability of high performance computers with their high processing power. These analysis techniques are known as 3 dimensional dynamic simulation and finite element analysis, it will describe elaborately, how 3 dimensional dynamic simulation can help to determine and calculate the load cycles in a chain and how this loads have a impact on fatigue life of a chain, so the designer can get a parameter through which by improving or chaining this parameters could lead to have improved fatigue performance of a chain links which are going to be designed. This technique will go on to illustrate the various and variety of different stages of a complete cycles of a fatigue improvements for a leaf chain and its links and also for a roller chains with multiple strands. Using these technique including the 3D dynamic simulation and the finite element analysis provides a key advantages is that one can do a optimization of each single link or a component and to look at the final end result on the whole chain without actually manufacturing it as a real leaf chain.

Facai Ren [6] chain drives are one of the critical component while dealing with the heavy loads or the power transmission on a heavy load capacity escalators. Performance of the chain drives in this specific areas are extremely important, so for the checking of the service time of a new chain drives are done by breaking test of that chain. As the operation of chain in escalator required a continuous motion of the chain over the supporting frame that include the sheaves or sprocket according to the requirement for the safe limits of loads, this also required a greater number of factor of safety for that chain drives. And for the determining the real fatigue life of the chain the test should be perform in a manner of cyclic loads under the influence of lubrication and optimum environmental conditions and also a test which include a cyclic loads under an extreme working conditions for the chain drive. The above test help to analyse the true fatigue conditions under the influence of working conditions which are of different kinds.

B. Fischer [7] these chain links are flexible in nature, so that are often used as a connecting link between chain and a hook through which load is to be lifted. By studying the purpose of the leaf chain one can find that it should be designed for the very large tensile load, so it is not designed for the diagonal pulls, rather than this it is design for clean tensile stress. In practice little effect of diagonal forces, which is a result of diagonal pull situations are often inevitable, while designing these chain a certain degree of security should be assured while such unscheduled load cases or uncertain force of action acting on leaf chain, this condition help to predict the production engineer that leaf chain may behave “tenderly”. In the present analysis of failure, the chain link delivered were no longer tempered or quenched, rather than this it is case hardened, which make it more resist to wear while performing its operation but it make also less tolerable against the various kind of bending forces which is a result of uncertain bending loads inevitably occurring with uncertain amount of diagonal pulls. As a result of these uncertain diagonal forces, leaf chain may get fractured and break while performing its operation, which leads to a dropping of loads during the lifting.

M. Chew [8] where there are motion between the running chain drives and the supporting elements causes a various types of impact acting on that drives, basically the magnitude of the impacts on the drives are a function of the speed of that chain, link plate pitch and the number of link plate present in the given length of the chain and also the overall weight distribution on each element of chain. The generated impulsive force on the each element of the chain is proportional to the amount of load under it work. By the help of the Lagrange equations for the impact calculation it was noticed that the effective weight reduces with the increase in length of chain.

G.E. Johnson [9] conducting experiment for investigating the amount of tension generated on the link plate of the chain drives, by this investigation we can identify the dynamic behaviour of a chain drives. This method include the mounting of a strain gauge on a side link plate of a chain, this help to determine the generated tension on a chain link plate during the usual operation of a chain over a wide range of loads condition and chain speeds. The generated output data from the installed instruments on the link plate was computed by a method called transfer of experimental functions, which was facilitated by Kjaer and Bruel dual channel analysis of spectrum.

C. Sai Virinchy [10] whenever a link plate of a chain drive are design, designer should choose a wide variety of material for the design purpose of the chain link plate to handle a very large amount of tensile loads, but in the efficiency point of view design should choose a material which is also light in weight and also able to withstand with high amount of stresses acting on it. So analysis of structure on a link plate of chain is carried out on a different material which is stainless steel and aluminum T761 alloy, as a result of it stainless steel with less distribution of stress over the structure cross-section.

## 3. CONCLUSIONS

After reading and analyzing the key parameters related with the chain drives (which consist an assembly of serially connected link plate with a help of pin) for the counterweight balancing in a machine tool, we can come to a conclusion that whenever these drive are in motion due to the sudden start and stop motion of the machine tool exerted extra load on the chain link which gradually increase or decrease in load causes a fatigue wear or many other structural wear in a chain link plate, various design parameters are taken in to account during process of chain design, while some parameters are constrains, working on fatigue wear resistance could increases a service life of a chain.

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